Evaluation of Kill Strips on Boll Weevil (Coleoptera: Curculionidae) Mortality in Pheromone Traps and Impact on Weevil Escape

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ABSTRACT A field study examined the temporal patterns of boll weevil mortality provided by two commercially available kill strips, Hercon VaporTape II and Plato Insecticide Strip, and to evaluate the impacts of these devices on weevil escape from traps. Both types of kill strips produced similar levels of weevil mortality with the exception of the last two inspection intervals (30 and 46 h after continual exposure to kill strips). At these intervals, the Plato Strip produced significantly higher mortality than the Hercon strip; however, these differences were numerically small (10 and 6%, respectively). Both types of kill strips produced a high level of weevil mortality in traps (>90%) after 46 h of exposure. On average, 5–8% of weevils escaped from traps whether a kill strip was present or absent. A strong temporal pattern of escape was observed, with ≥90% of escape occurring within the first hour after weevils were introduced into traps. Because ≥90% of escape occurred within the first hour weevils were in the traps and <3% of weevils died during the first hour of exposure to kill strips in traps, use of kill strips in large-scale boll weevil management programs is not justified on the basis of reduced weevil escape.

KEY WORDS boll weevil, *Anthonomus grandis*, kill strips, pheromone traps

ERADICATION PROGRAMS directed against the boll weevil, *Anthonomus grandis* Boheman, rely almost exclusively on pheromone traps to detect boll weevils, assess populations, and indicate the need for insecticide treatment. These traps are generally placed adjacent to cotton fields and are checked weekly from plant emergence until the cotton stalks are destroyed. In addition to a pheromone lure, each trap is typically equipped with an insecticide-impregnated plastic kill strip. The kill strips are intended to kill weevils soon after capture, thereby reducing the incidence of weevil escape and decreasing trap handling time during servicing. Currently, at least two types of boll weevil kill strips are commercially available. One is the Plato Industries Insecticide Strip (Plato Industries, Houston, TX; 18.6% wt:wt dichlorvos [2,2-dichlorovinyl dimethyl phosphate]), which is currently used by the Texas Boll Weevil Eradication Foundation. Another is the Hercon Vaportape II (Hercon Environmental, Emigsville, PA; 10% wt:wt dichlorvos).

Despite the widespread use of kill strips in eradication programs and large-scale trapping studies, detailed scientific evidence documenting their efficacy in the field is not available. Hardee et al. (1996) examined their impact on trap captures, and concluded that there was no statistical justification for their use in traps. However, these authors advocated continued use of kill strips because they were relatively inexpensive, and presumably simplified operation of traps. Although kill strips are relatively inexpensive, they represent a substantial economic investment in eradication programs because of the large number of traps involved. Furthermore, our prior experiences have indicated that mortality provided by kill strips was minimal or occurred too slowly to substantially impact the efficiency of trap servicing. Additionally, the impact of kill strips on weevil escape from traps has not been demonstrated. Prevention of escape is particularly important when cotton is fruiting rapidly because trap captures are typically low during this part of the growing season. Minimization of escape is critical during the maintenance phase of eradication programs because of the reliance on traps for detecting reinfestations and indicating the need for insecticide treatment.

Because kill strips are extensively used in boll weevil eradication programs and frequently used in large-scale trapping studies, an understanding of their impacts on the dynamics of trap captures and trapping systems is essential. Our objectives were to examine the temporal patterns of mortality provided by two commercially available kill strips, and to evaluate the impacts of these devices on weevil escape from traps.

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Materials and Methods

Adult boll weevils were reared from infested squares collected from cotton plants in commercial fields near College Station, TX. Each collection of infested squares was held in a 20 × 20 × 20-cm screened Plexiglas cage at 29.4 ± 1°C and a photoperiod of 13:11 (L:D) h. Beginning on the fifth or sixth day after square collection, pupae were harvested from squares daily and were held in Petri plates containing a thin layer of moistened vermiculite. Plates containing pupae were held under the same conditions as collected squares and were checked at least once daily for newly eclosed adults. Adults (<24-h-old) were transferred to screened cages on the day of eclosion. Adults that eclosed over several consecutive days were typically pooled within a single cage, and were held in the laboratory (≈23°C). These weevils were provided one boll, 15- to 25-mm in diameter, for every 10 weevils, and were supplied water in a diet cup with a cotton wick extending through the lid. Bolls were replaced three times weekly.

The experiment was a randomized complete block design with six lines (blocks) of three traps each. Treatments included the Hercon Vaportape II kill strip, Plato Industries Insecticide Strip, and an untreated control (no kill strip). Traps were supported on electrical conduit at a height of ≈1 m above the ground surface. The entrance through the apex of the screen cone leading into the capture container of each trap was sealed with a bead of hot glue to prevent weevil escape. Blocks and traps within blocks were separated by 1.5 m. Treatments and groups of weevils were randomly assigned to individual traps within each block on the day of assay.

On the morning of assay, 105 (95 in the last run) 6- to 14-d-old weevils were selected from the feeding cages and were confined to 29.5-ml diet cups in mixed-sex groups of five weevils each. Care was taken to select only apparently healthy weevils with all appendages intact. Groups of weevils were held in a shaded area within a service bay for at least 1 h before they were introduced into traps. The bay doors were opened during this time to allow weevils to acclimate to outside temperature conditions. At ≈0900 hours (CDT), traps were placed in their randomly assigned positions within each block and were equipped with the appropriate kill strips. At ≈1000 hours, a group of weevils was introduced into the capture container of each trap (five weevils per trap). Remaining weevils were used to replace any weevils lost during introductions into traps. A single trap, equipped with a HOBO datalogger (Onset Corp., Pocasett, MA) programmed to record temperature under the trap base at 15-min intervals, was placed in the center of the grid of traps. Weevil mortality was recorded at 1, 2, 4, 6, 8, 22, 26, 30, and 46 h after the weevils were placed in the traps. The experiment was conducted six times between 11 July and 2 September, using new kill strips each time.

The condition of weevils used in the study was characterized on the basis of fat body development, which was assessed by dissection. In each of the first five runs, 10 of the original 105 weevils were randomly selected and dissected at the beginning of the assay. In the last run, 10 surviving weevils from a random sample of the control traps were dissected after the last mortality inspection interval. Weevils were classified as "lean" (fat body not hypertrophied, usually grayish and sheet-like) or "fat" (fat body white, in distinct globules, and obscuring much or all of the internal organs).

The influence of kill strips on weevil escape from traps was evaluated using the same experimental design and procedures as in the efficacy study with the following exceptions: (1) trap entrances into capture containers were unobstructed, (2) weevils were individually marked with nontoxic paint (Speedball Painters, Hunt Manufacturing, Statesville, NC) and an identifying number on one elytra, (3) no temperature data were recorded, (4) weevil condition was assessed by dissection of 10 weevils selected from the untreated control traps at the last inspection interval, and (5) both weevil mortality and escape were recorded at each inspection interval. Weevils were considered to have escaped if they were not found within the confines of the plastic capture container. In some cases, escaped weevils were subsequently recaptured. The experiment was conducted six times between 2–29 August 2001.

Mortality and escape data were converted to proportions and arcsine-square root transformed (Zar 1984) before analysis. Transformed proportions were analyzed by repeated measures analysis of variance using the REPEATED statement of the SAS procedure PROC GLM (SAS Institute 1998). The model for both the mortality and escape analyses included main effects of run, block, and treatment, a repeated factor of time of inspection, and terms for the interactions of these factors. In each analysis, the sphericity test either indicated the Huynh-Feldt condition was strongly rejected ($P < 0.0001$), or the test could not be conducted because of a negative determinant. Thus, Wilk Lambda was used to assess the significance of model terms containing the repeated factor (hours). When main effects were significant, corresponding means at each level of the repeated factor were separated using the REGWQ option of the MEANS statement (SAS Institute 1998).

Results and Discussion

Mortality levels differed among treatments ($F = 467.55$; df = 2, 50; $P < 0.001$) and times of inspection (Wilk Lambda = 0.009; $F = 519.63$; df = 9, 42; $P < 0.001$). Mortality was generally higher in the kill strip treatments than in the untreated control, and tended to increase with time. However, the significant time-by-treatment interaction (Wilk Lambda = 0.0123; $F = 37.36$; df = 18, 84; $P < 0.001$) indicated the temporal patterns of mortality differed among treatments (Fig. 1). At the first inspection interval (1 h), mortality levels were similar among treatments. Levels of mortality in the untreated controls remained low (<5%)

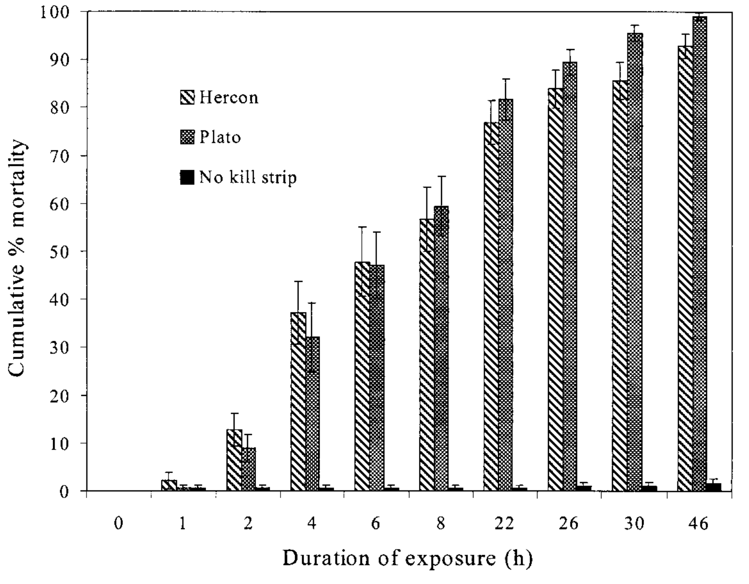

Fig. 1. Mean (±SEM) cumulative percentage of mortality of weevils in pheromone traps equipped with and without kill strips.

at subsequent inspection intervals whereas mortality in both kill strip treatments gradually increased to >90%. Mortality levels produced by the two types of kill strips were similar with the exception of the last two intervals (30 and 46 h). At these intervals, the Plato strip produced significantly higher mortality than the Hercon strip; however, these differences were numerically small (10 and 6%, respectively). Mortality levels in the untreated controls were much lower than we expected based on previous trapping experiences (unpublished data). This low mortality may have been a consequence of the condition of the weevils used in the current study. Only vigorous, recently fed, and relatively young weevils were used, and dissections indicated that >50% of the weevils used in each run of the experiment (>90% in last three runs) contained hypertrophied fat bodies. In contrast, dissections conducted in conjunction with on-going trapping studies have indicated that most weevils responding to traps contain little or no fat body reserves.

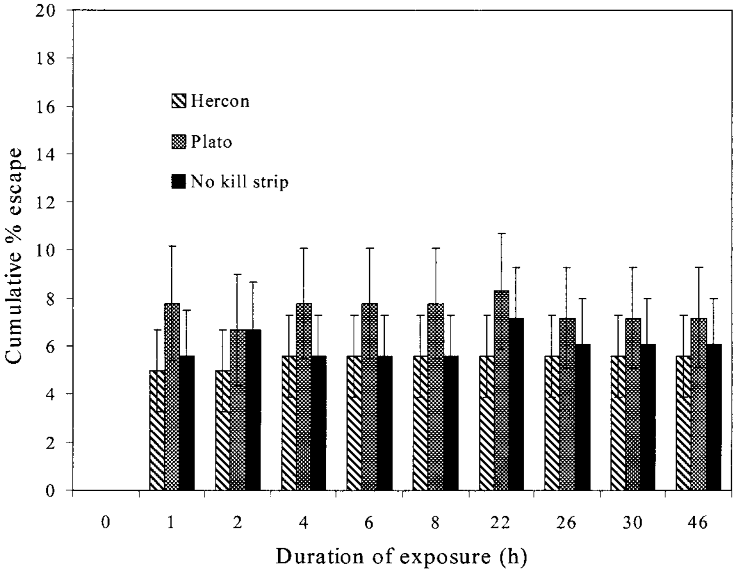

Fig. 2. Mean (±SEM) cumulative percentage of weevils escaped from pheromone traps equipped with and without kill strips.

Table 1. Temperature conditions under a boll weevil trap base during the kill strip efficacy study, 2001

Run	Temperature (°C)		
	Avg	Min	Max
1 (11–13 July)	30.4	20.5	40.5
2 (16–18 July)	30.8	20.5	42.0
3 (18–20 July)	30.1	22.5	44.0
4 (23–25 July)	31.6	21.5	45.0
5 (25–27 July)	29.8	19.5	44.5
6 (30 Aug–1 Sept)	NA	NA	NA

Mortality levels differed significantly among runs ($F = 41.52$; df = 5, 50; $P < 0.001$), and the significant time by run interaction (Wilk Lambda = 0.017; $F = 6.31$; df = 45, 191; $P < 0.001$) indicated that the temporal patterns of mortality differed among runs. Mortality tended to be higher, and to occur somewhat earlier, in the runs conducted during late-July compared with those conducted in mid-July. No trend was observed in the temperature data that would explain these differences. It is possible that these differences could have resulted from differences in vigor or susceptibility to the toxicant among weevil cohorts, or from unknown factors that may have affected the volatilization rate of dichlorvos from the kill strips.

The proportion of weevils escaping from the traps did not differ among treatments ($F = 0.20$, df = 2, 50; $P = 0.822$), blocks ($F = 0.65$; df = 5, 50; $P = 0.661$), or runs of the experiment ($F = 0.90$; df = 5, 50; $P = 0.490$). On average, 5–8% of weevils escaped from traps whether a kill strip was present or absent. A strong temporal pattern of escape was observed (Wilk Lambda = 0.559; $F = 7.26$; df = 5, 46; $P < 0.001$), with ≥90% of escape occurring within 1 h after weevils were introduced into the traps. Examination of interaction terms indicated this pattern was consistent across treatments (Wilk Lambda = 0.802; $F = 1.07$; df = 10, 92; $P = 0.392$), blocks (Wilk Lambda = 0.707; $F = 0.67$; df = 25, 172.38; $P = 0.877$), and runs of the experiment (Wilk Lambda = 0.66; $F = 0.82$; df = 25, 172.38; $P = 0.715$).

Results regarding the temporal pattern of escape were consistent with our previous observations during trap design studies. In those studies, most weevils escaping traps were observed to do so within a short time after initial capture (unpublished data). The temporal pattern of escapes was also responsible for the lack of differences in escape among kill strip treatments, because most escapes occurred before the kill strips produced substantial levels of mortality. Also, it is not known whether weevils exposed to the kill strips died or survived after their escape; however, it should be noted that one escaped weevil was collected alive from a nearby cotton field several days after the study was terminated.

Our results indicated that both types of commercial kill strips produced a high level of weevil mortality in pheromone traps. However, despite using new kill strips in each run of the study, observed mortality occurred relatively slowly, and consequently did not impact weevil escape. Additional studies will be required to determine if field-aging of the kill strips further diminishes their ability to kill captured weevils. Although kill strips are relatively inexpensive, the use of large numbers of these devices in large-scale trapping studies and by eradication programs represents a substantial economic investment. In light of our findings, continued use of kill strips in boll weevil eradication and maintenance programs as well as in large-scale trapping studies is not justified on the basis of reduced weevil escape.

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References Cited

Hardee, D. D., A. A. Weathersbee, III, J. M. Gillespie, G. L. Snodgrass, and A. R. Quisumbing. 1996. Performance of trap designs, lures, and kill strips for the boll weevil (Coleoptera: Curculionidae). J. Econ. Entomol. 89: 170–174.

SAS Institute. 1998. SAS System for Windows, version 7.0. SAS Institute, Cary, NC.

Zar, J. H. 1984. Biostatistical analysis, 2nd ed. Prentice-Hall, Englewood Cliffs, NJ.

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